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STUDY OF CARBON MONOXIDE EXPOSURES OF RESIDENTS OF WASHINGTON, D.C.

by

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16. ABSTRACT

The paper will describe a study conducted in the Washington, D.C., area during the winter of 1982-83 for the purpose of measuring the distribution of carbon monoxide (CO) exposures of a representative population of the area. The population distributions were determined by direct measurement of CO with personal exposure monitors (PEM) through the use of statistical inference from a statistically drawn sample. The study also provided data (through the use of individual diaries) to determine exposure to CO as a function of concentrations within significant microenvironments (e.g., home, in transit, work, leisure) and individual activity patterns. Breath samples were also collected from sample individuals. The population of inference for the study was non-smoking adults (age 18-70) in the D.C. area which was estimated to include about 1.22 million individuals. The actual number of individuals sampled with usable CO data was 712. Each sampled individual carried a CO PEM for a 24-hour period and also completed a diary to record his corresponding activities and locations. Results from the study indicated that the estimated mean of the maximum hourly CO concentrations (over a 24-hour period) was 6.74 ppm and the estimated mean of maximum 8-hour concentrations was 2.79 ppm. These mean levels varied by type of day (weekdays versus weekends), occupation, commuting characteristics, and the

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1. Introduction

As the control of emissions increases, the burden of proof on the Environmental Protection Agency (EPA) to show that a particular level of emission control is justified also increases. It has become more and more important to show that a given level of control is justified for each air pollutant.

A critical factor in determining the degree of risk to the population is the exposure of members of the population. Reference 1 describes previous monitoring of airborne pollutants based on fixed-site monitoring. However, for many pollutant concentrations, ambient fixed sites often differ significantly from the concentrations with which people actually come into contact. This paper describes a study undertaken by the Research Triangle Institute (RTI) and funded by the EPA to develop a methodology for determining the public's exposure to air pollutants with known precision and accuracy.

In particular, a study plan was formulated to develop and field test a population exposure methodology using carbon monoxide (CO) while making sure that the methodology was broad enough to accommodate other pollutants of concern. The specific objectives of this study were the following:

- To develop a methodology for measuring the distribution of carbon monoxide (CO) exposures of a representative population of an urban area for assessment of the risk to the population.
- To test, evaluate, and validate this methodology by employing it in the execution of pilot field studies in Denver, Colorado, and in Washington, DC.
- To obtain an activity-pattern data base related to CO exposures.

The specific reasons for selecting carbon monoxide for primary emphasis in the current study are also given in reference 1.

The study was carried out in Washington, DC, and Denver, Colorado, during the winter of 1982-83 (the period of the year with expected maximum ambient CO concentrations). The population exposure profile was determined by direct measurement of CO with personal exposure monitors (PEMs) through the use of statistical inference from the statistically drawn sample. The study provided sufficient data to determine exposure as a function of concentrations within significant microenvironments (home, in-transit, work, and leisure) and individual activity patterns. This paper describes the sampling in Washington D.C. and Denver, Colorado and the field work and analysis of results in Washington, D.C. (Pedco Environmental performed the field work in Denver, Colorado).

It is extremely important to note that the study not only developed and tested methodology for measuring the distribution of CO in an urban area but also produced direct estimates of CO exposure that apply to two large metropolitan areas. In addition, a very important product of this work is a unique and valuable data base on individual exposures to CO and the corresponding activities that led to these exposures.

2. Summary of Study Design and Procedures

The target population consisted of the non-institutionalized, non-smoking adults (ages 18 to 70) in the metropolitan areas in and around Denver, Colorado and Washington, DC. Briefly, a probability sample of the target population was selected in both cities. This sample was a stratified, three-stage, probability-based design. Area sample segments defined by Census geographic variables were selected at the first stage of sampling. Households were selected at the second stage, and a household member was administered a short screening interview covering all household members to identify individuals with characteristics believed to be postively correlated with CO exposure. Thus, household members with these characteristics could be oversampled in the third stage. Donnelley Market Corporation listings were used to help select households for the screening interview. The third stage sample was a stratified sample of screened eligible individuals (i.e., non-smoking, aged 18 to 70). The individuals in the third stage sample were administered a Computer Model Input Questionnaire and were asked to carry a personal CO monitor and an Activity Diary for 24 or 48 hours (for Washington and Denver, respectively). A breath sample was also requested from these individuals and they were asked to fill out a Household (Study) Questionnaire which provided information on themselves and on their home and work environments. The third stage sample design also allocated individuals to specific days within the sampling period. A detailed discussion of the sample design is given in references 2 and 3.

More specifically an initial telephone screening was carried out in both Denver and Washington, DC by using a Computer Assisted Telephone Interviewing (CATI) system. This initial screening was supplemented by limited field screening in both sites. Specific information collected during this interview included: time spent in regular commuting and smoking status of each household member, as well as presence of gas appliances and attached garages in their residences. After the initial screening and the initial selection of potential participants, another telephone interview was conducted. The purpose of this call was to contact the selected individual to further explain the study and attempt to enroll him(her) into the study. If the individual agreed to be part of the study, an appointment was established for a field interview.

Participating individuals were met at their home or other convenient location and given all study materials and a cash incentive. These participants carried both a PEM for the 24 hours of their participation and an Activity Diary in which to record a description of their activities. Participants were requested to push a button on their PEM every time they changed activities and to record descriptions of the new activities in their diaries. In addition, for a small sample of Washington, D.C. participants, a GE/HP PEM was used which allowed the participant to also enter an activity code into the monitor[2].

The results of the telephone screening and field activities for the study are described in detail in reference 2. Briefly, 5818 household screenings were attempted by RTI in Washington, DC and 3162 were attempted in Denver, Colorado. The successful screening rates were 75.8 percent in Washington and 70.4 percent in Denver. From these telephone and field

screenings, 5423 eligible respondents were identified in Washington and 2232 in Denver. From this population of eligibles, 1987 individuals were selected for participation (i.e., to carry a PEM) in Washington and 1139 in Denver. Of these selected individuals, 58 percent actually scheduled appointments to carry a PEM in Washington. Results for Denver are given in reference 4. Finally, 35.8 percent of the individuals in Washington selected to participate contributed usable CO monitor data. This represented 712 sample respondents. Instrument failure was one of the major reasons for the low response rate. Specifically, CO data was not collected or was unusable for analysis purposes for 232 respondents (22% loss rate) due to monitor failure or malfunction. Usable CO breath data corresponding to the usable CO monitor data was collected on 659 sample respondents. Figure 1 gives a summary of the three-stage sampling results in Washington, D.C. It is important to realize that the response rates for a study of this complexity will always be relatively low as compared to studies where only a questionnaire is administered to a respondent (i.e., 85 to 95 percent response rates). It is RTI's experience with studies of this type which require a substantial respondent burden that 50 to 60 percent response rates are typical. As indicated above, the current study had a lower than usual response rate primarily due to instrument failure.

In order to successfully implement the study in Washington, DC, a field office/laboratory was established in the offices of the Metropolitan DC Council of Governments. This office was used for several purposes including supervision of field staff, storage of supplies, maintenance of records, allocation of field assignments, and maintenance and repair of the PEMs. This office was visited twice nightly by all interviewers to receive PEMs and data collection forms for that evening and for return of completed study materials including the PEMs used the previous 24 hours. All calibrations of the PEMs during the study were carried out in this field laboratory. In addition to the field supervisor for the interviewers, the field laboratory was staffed with two full-time technicians working seven days per week throughout the study. A detailed description of the PEMs (COED-1s and GE/HPs) used in this study and the extensive daily technical support that they required is given in reference 2.

As mentioned above, breath samples were collected from respondents during the study. This required RTI to evaluate a method for collecting and measuring alveolar CO. This evaluation is described in detail in reference 2.

Throughout the field work, a quality assurance program was maintained for the sampling and analysis procedures employed. This included using field standards to calibrate all the CO monitors. The monitors were subject to calibration (two-point, zero/span) before they were put in the field and 24 hours later when they were returned from the field. The comparison of the two calibration curves was used to assign validity codes to the PEM data. Other quality control procedures employed were: a ten percent check of data transcribed from monitor memory to field data sheets; monitoring control charts on each monitor describing the course of differences between pre-sample and post-sample span, zero, battery voltage, and flow rate values; collecting duplicate colocated samples for the purpose of characterizing monitor precision; performing external and internal QA and QC

audits; performing multipoint calibrations to assess monitor linearity during the study; and obtaining duplicate breath samples from respondents. As an example of the results from this QA program, an analysis of variance of the duplicate PEM measurements was run. This analysis considered person-to-person, hour-to-hour, and measurement variation and found that about 5 to 6 percent of total variation among duplicate readings was due to deviations in measurements made by two PEMs.

After the field work was completed, the data were returned to RTI where detailed editing of the data was carried out by RTI editors. The data were then entered into computer files using RTI's mini-computer data base entry system. All data were keyed and then 100 percent key-verified. Sampling weights were computed according to prescribed formulas based on the sampling design[3]. This involved extensive computations so that the weights could be used to draw inferences to the target populations.

Estimates were computed of household and individual characteristics in Washington and Denver using results from the Household Screening Questionnaire. When possible, these estimates were compared with corresponding Census estimates. Detailed statistical analyses were then carried out using computer data files with PEM CO and activity diary data. Estimates computed during this analysis were weighted estimates for the population of inference - adult non-smokers in the Washington, DC metropolitan area. Standard errors of estimates were produced by using specially written software designed for analysis of data from complex sample surveys[5]. These analyses included computing statistics describing diurnal patterns, maximum hourly CO concentrations, maximum 8-hour CO concentrations, and mean hourly CO concentrations. CO hourly level comparisons were also made for 3 occupational groups; 6 commuter groups and 4 categories describing the use of gas stoves. Estimates were also produced for CO exposure levels for various activities (e.g., in transit) and locations (e.g., indoors-at residence).

3. Results

Screening Estimates

Using the data collected in the Washington, DC and Denver metropolitan areas with the Household Screening Questionnaire, weighted estimates were computed of population characteristics. These estimates were based on screening interviews in 4394 households in Washington and 2128 households in Denver. In particular, the population estimate for the number of households in the two areas was 953,714 for Washington and 345,163 for Denver. Population estimates of percentages of households with various characteristics were as follows:

Household Characteristics	Washington		Denver	
	Total	Percentage	Total	Percentage
Use Fireplace	316,925	33	103,211	30
Use Wood Stove	37,721	4	20,314	6
Use Gas Furnace	532,347	56	245,902	71
Use Gas Stove	609,029	64	85,542	25
Use Gas Hot Water	542,855	57	269,810	78
Have Attached Garage or Multi-Family Garage	165,919	22	108,934	35

In addition to household characteristics, several estimates were also obtained for individuals' characteristics in the two areas. For example,

Individual Characteristics	Washington		Denver	
	Total	Percentage	Total	Percentage
Male	1,286,056	48	415,730	47
Smokers (13 years or older)	639,739	33	244,884	38
Work (13 years or older)	1,333,061	70	464,960	72
Travel ≥ 3 times/week	1,606,757	84	530,420	82

Additional estimates are given in reference 2.

Estimates of CO Exposure in Washington, D.C.

The population of inference--adult non-smokers in the D.C. area--was estimated to include about 1.22 million individuals. Unless specifically noted otherwise, all results shown in this section apply to this population or to some specified subgroup of this population. The results also apply only to the winter of 1982-83, as this was the period of data collection.

Subgroups of the population deemed to be of particular relevance to CO exposure that are used in the analyses are occupational exposure, exposure through travel/commuting, and exposure through gas cooking. Some of the results in this section are also shown by type of day--days of high potential CO exposure versus other days; and weekdays versus weekend days (actually, Friday evening through Sunday evening).

Diurnal Patterns. Figure 2 shows the estimated mean diurnal exposure patterns of CO exposures for the Washington area population of inference for weekdays and for all days. These (weighted) estimates, and their approximate standard errors, are given for all days, for weekdays and weekend days, and for days of low and high CO levels (as indicated by fixed site monitors) in reference 2.

The pattern for weekdays (and, hence, for all days) exhibits the well-known effect of commuting traffic, with dramatic increases in CO levels between 7-9 a.m. and 4-7 p.m. The lowest levels occur between 4-6 a.m. For weekend days, the increase in CO level during the morning is much less pronounced than that for weekdays. The p.m. peak is of about the same magnitude, however. The late night and early morning hours also appear to have higher CO levels on weekend days, although this difference cannot be declared as statistically significant.

Maximum Hourly Concentrations. The maximum of the hourly CO concentrations for each individual (over 18 to 26 hourly values) was determined for the 712 respondents. The analysis of this variable is shown in Table I. For the overall population, the mean of the maximum hourly values was estimated to be 6.74 ppm (during the winter 1982-83 data collection period). As indicated in Table I, this mean level varied by type of day, with higher maximum hourly CO values, on average, occurring on weekdays (7.35 ppm). The mean level also varied, in accordance with a priori expectations, depending on individuals' occupational and traveling characteristics. Persons working outside the home, especially those in occupations with potentially high exposures, exhibited higher maximum hourly CO concentrations, on average, than those persons not working outside the home. In fact, in the high-exposure occupational category (an estimated 4.63% of the overall population), about 24% exhibited a level above the one hour standard level for carbon monoxide (35 ppm), and over half of this subgroup was estimated to have maximum hourly CO exposures over 9 ppm. Figure 3 illustrates the differences in maximum hourly CO levels for the 3 occupational groups examined. As shown in Figure 4, commuters, especially those with longer traveling times, also showed higher CO exposures (based on their one-hour maximum values) than non-commuters. Those commuters indicating total travel of more than 15 hours per week, for instance, had a mean estimated maximum hourly concentration of 12.01 ppm, as compared to 4.94 ppm for non-commuters. Persons having unvented gas stoves also showed slightly higher means than those persons not having gas stoves (an average maximum hourly concentration of 7.05 ppm versus 6.82 ppm).

Maximum 8-Hour Concentrations. Table II shows the results of the analysis of this exposure measure. For the overall population, the estimated mean 8-hour CO concentration was 2.79 ppm; it was estimated that about 4% of the overall population had levels exceeding 9 ppm, the 8-hour standard level. These were primarily persons in high-exposure occupations and/or persons with extensive amounts of motor vehicle travel. The maximum 8-hour mean for the group with high occupational exposures was 7.51 ppm; for commuters with 16 or more hours of total travel per week, the mean was estimated to be 3.80 ppm. Persons with gas stoves in their homes also appeared to have higher 8-hour levels, on average, than persons without such stoves. In general, the only subgroup with a relatively large percentage over the 8-hour standard level was the high occupational exposure group (28.1% over 9 ppm).

Tests Between Exposure Groups. Approximate pairwise tests of significance were conducted to determine if the various population subgroups were different in regard to their average maximum hourly and average maximum 8-hour CO exposures (the tests are approximate since standard errors for survey based statistics are approximations). The results, shown below, indicate no significant differences between low and high CO days or between the various categories of stove type. The non-significance between high and low CO days, as arbitrarily defined in this report (see Table I), is not surprising considering that the winter of 1982-83 in Washington, D.C. was very warm and had only six days where any of the fixed stations had a maximum 8-hour average greater than the 9 ppm CO standard. Significant results are indicated for several other groups: persons not working outside the home versus those that do; persons with low occupational exposure versus

those with high occupational exposure; commuters versus non-commuters; and commuters with less than 6 hours of total travel per week versus commuters with 6 or more hours per week. Weekdays versus weekend days are significantly different only for the one hour maximum. The asterisks indicate statistical significance at the 5% level and no asterisk indicates the test was not significant at the .05 level.

Population Subgroup	Maximum 1-Hour CO Conc (ppm) Mean	Diff	Maximum 8-Hour CO Conc (ppm) Mean	Diff
Low CO days	6.71		2.72	
High CO days	6.82	.11	3.03	.31
Weekdays	7.35		2.94	
Weekend days	5.30	-2.05*	2.43	-.51
Gas stove at residence-vented	6.40		2.99	
Gas stove at residence-unvented	7.05	.65	3.03	.04
Gas stove at residence-unvented	7.05		3.03	
No gas stove at residence	6.82	-.23	2.55	-.48
Persons not working outside home	5.22		2.35	
Persons working outside home	7.38	2.16*	2.98	.63*
Persons with low occupational exposure	6.34		2.66	
Persons with high occupational exposure	22.11	15.77*	7.51	4.85*
Non-commuters (less than 3 times/week)	4.94		2.30	
Commuters	7.06	2.12*	2.88	.58*
Commuters--all travel = 0 - 5 hrs/wk	5.04		2.35	
Commuters--all travel = 6+ hrs/wk	7.90	2.86*	3.09	.74*

* Difference between two means significant at .05 level;
no * indicates difference not significant at .05 level.

Analysis of Activities and Associated CO Exposures. Based upon frequency counts of the various activity and location codes from the respondents' diaries, a set of five major and sixteen minor environments were developed. These are listed in Table IV. The time spent in each of these environments was determined by adding times over the activity segments for each sample member. Similarly, by time-weighting the activity segments, the average CO exposure level for each individual was determined for each environment (e.g., if an individual was in transit for 3 hours with an average CO level of 5 and later was in transit for 1 hour with a CO level of 3 then his time weighted average was 4.5).

In addition to the environments, times and CO levels by activity type were determined in a similar manner (see Table III). The "sleep" activity was separated from the "suspected sleep" activity in this case, whereas for the environments shown in Table IV, these two types of segments were treated as one.

Activity Patterns and Carbon Monoxide Exposures. Table III characterizes the activity patterns of the adult non-smoking population in the D.C. area and shows estimates of the CO exposure levels for the various activity types. The activities have been ordered in accordance with the estimated mean CO levels (highest to lowest). The table shows the estimated size of the exposed population as a percentage of the total population who were in-

volved in a particular activity (i.e., the number of persons exposed to CO through the given activity). Then, for this exposed population, the amount of time involved in the activity is then characterized by the mean time duration. The table indicates, for instance, that about 40% of the total population engaged in the activity "indoor chores". For these individuals, the mean amount of time in this activity was 2.18 hours. The remaining 60% of the total population did not engage in this activity (i.e., had a time duration of zero hours). The table shows that the average time spent in "transit, travel" was 2.07 hours (among those persons with this activity during an 18-26 monitoring period), that "workers" averaged 6.63 hours at work, etc.

In addition, the table indicates the percentage of the exposed population having CO exposure levels above 4 ppm. The estimates apply only to those persons actually involved in the particular activity. Note that 41% of the population exposed to CO in parking garages experienced CO levels above 4 ppm while in that environment.

Two general observations concerning the results of Table III that deserve mentioning are (1) the ranking of activities, with minor exceptions, is as one would expect (e.g., in parking garage and in transit have, by far, the highest averages). There is considerable overlap in the definitions of activities. This, along with some bias probably introduced by respondents' omissions of activities from their diaries, probably accounts for the exceptions. The most notable exceptions are the higher than expected ranking for "doctor or dentist office" and the lower-than-expected ranking of "outside house - chores". (2) The distributions of CO exposures appear to be skewed to the right for all activities; this is indicated not only by the estimated percentiles, but also by the fact that the mean levels exceed the median levels.

Table IV provides summaries of the analysis of time duration and the CO exposure levels by type of environment. This table indicates that the average time indoors at the residence was 17.63 hours (note, this average includes time spent at the residence on weekends). The mean time in a parking garage (for those so exposed) was 48 minutes; however, the median time[2] was only 11 minutes. This indicates, as might be expected, a highly skewed distribution. Table IV again indicates the relatively high CO levels in parking garages (mean = 10.36 ppm). The "in transit" and outdoor parking environments also exhibit relatively high levels (means of 4.51 ppm and 4.67 ppm, respectively).

Statistical tests were performed for the four major environments ("unknown" is excluded) to determine if the mean exposure levels were different. The four estimated means are shown below:

	Average CO Level(ppm)
(1) indoors - at residence	1.19
(2) indoors - not at residence	2.04
(3) outdoors	2.62
(4) in transit	4.51

The average CO exposure level for the first of these environments was significantly lower than that of the latter three, and the fourth environ-

ment was significantly higher than any of the first three environments. The approximate tests utilized a 5% level of significance. Several additional results for CO exposures (e.g., for high and low CO exposure days) are given in reference 2.

Comparisons of Fixed Site and PEM Levels. During the period of the Washington, D.C. field study, from November 8, 1982 through February 25, 1983, EPA collected CO data at eleven fixed sites in the Washington, D.C. area. As described previously these data were used to classify days as low or high CO days. Summary statistics for these stations (e.g., maximum hourly levels) are given in reference 2. In general, CO levels at these stations were relatively low during the sampling period with only two stations having daily maximum 8-hour values exceeding 9 ppm (one site for 1 day and the other site for 5 days). At the present time these data are also being compared with the PEM levels to determine the relationships between fixed and personal levels. Preliminary correlation analyses indicate that in general PEM and fixed site data are not well correlated (e.g., the R^2 between the nearest fixed station and office and home PEM levels are only .06 and .02, respectively). Detailed results of this analysis will be reported when they become available.

4. Conclusions

Based on the experience gained during the Washington, D.C. and Denver PEM CO studies, the methodology developed, with some modifications[2] may be used effectively in other areas of the country for collecting PEM data. Experience gained during this initial study will improve the execution of such similar studies. Modifications that are suggested include a different sampling design using the classified telephone directory listings, improvements in the CO monitors, and additional refinement of the method used to collect activity data. These modifications should make the methodology more cost effective, improve the response rate, and lead to more accurate activity information.

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Figure 1. Outline of Washington, D.C. three-stage sample.

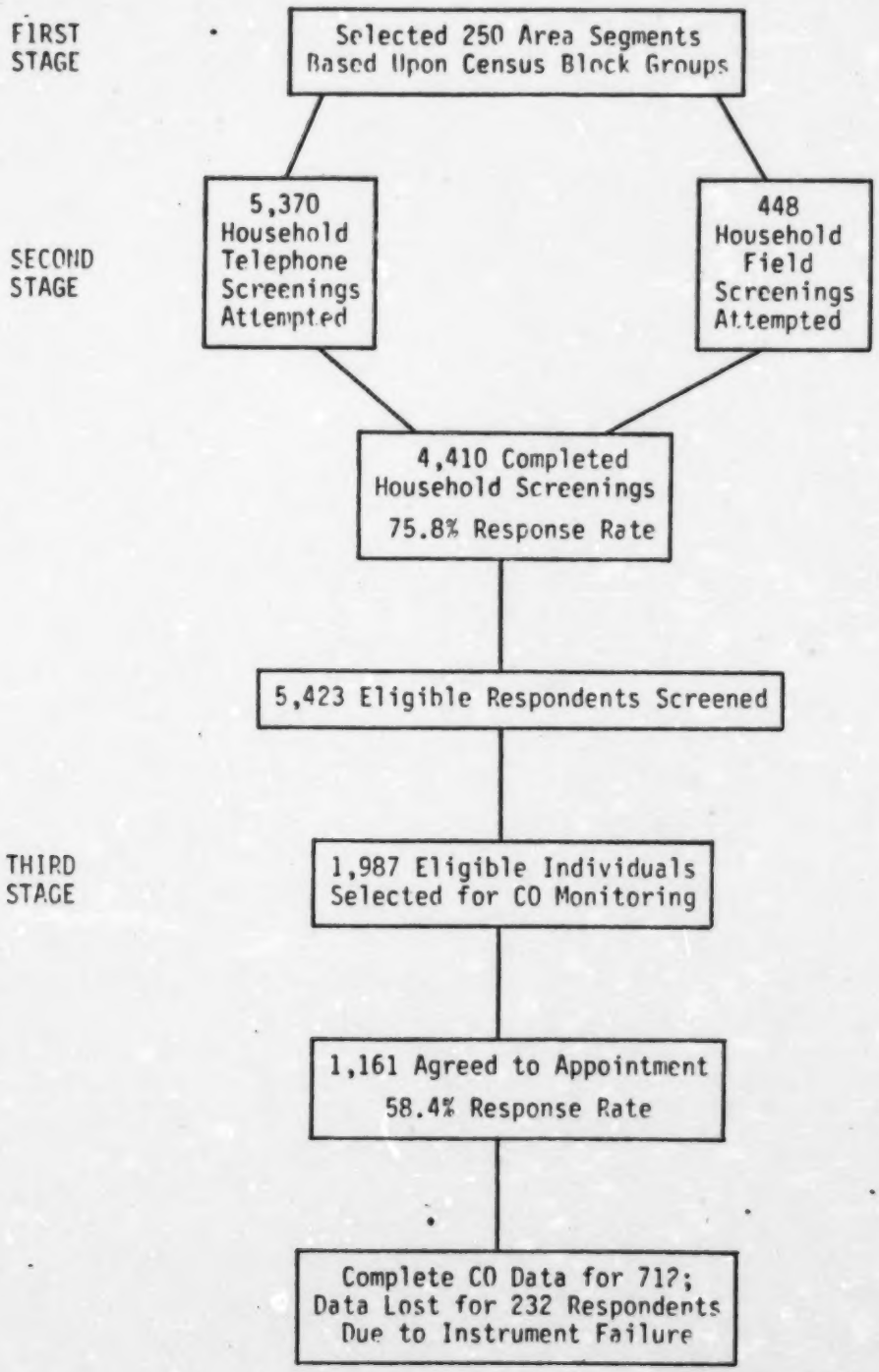
FIRST STAGE
Selected 250 Area Segments Based Upon Census Block Groups
SECOND STAGE
5,370 Household Telephone Screenings Attempted
448 Household Field Screenings Attempted
4,410 Completed Household Screenings
75.8% Response Rate
5,423 Eligible Respondents Screened
THIRD STAGE
1,987 Eligible Individuals Selected for CO Monitoring
1,161 Agreed to Appointment
58.4% Response Rate
Complete CO Data for 712; Data Lost for 232 Respondents Due to Instrument Failure

Figure 2. Average CO exposure levels, by hour of day.

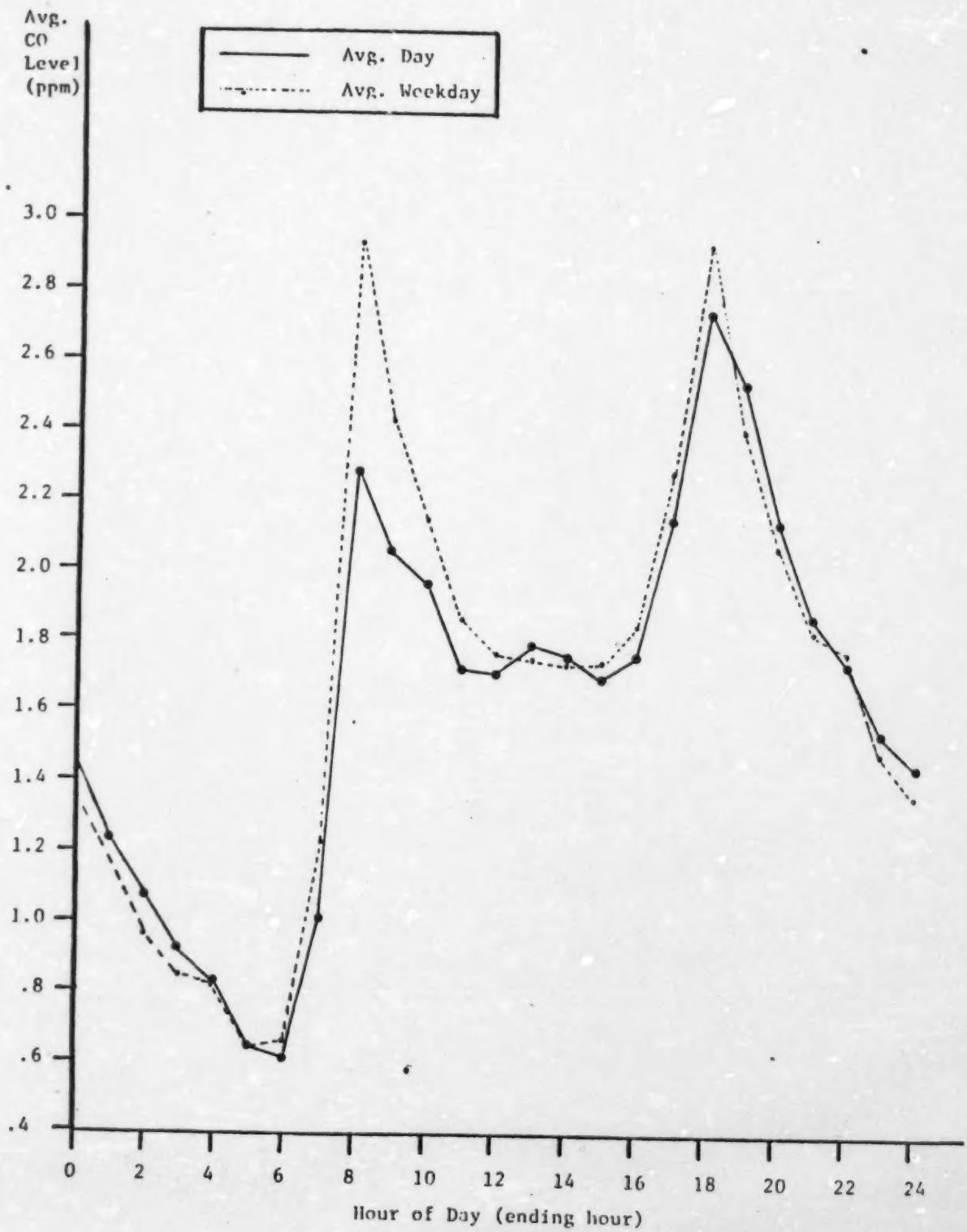

Figure 3. Maximum hourly CO concentrations by occupational exposure, Washington, D.C.

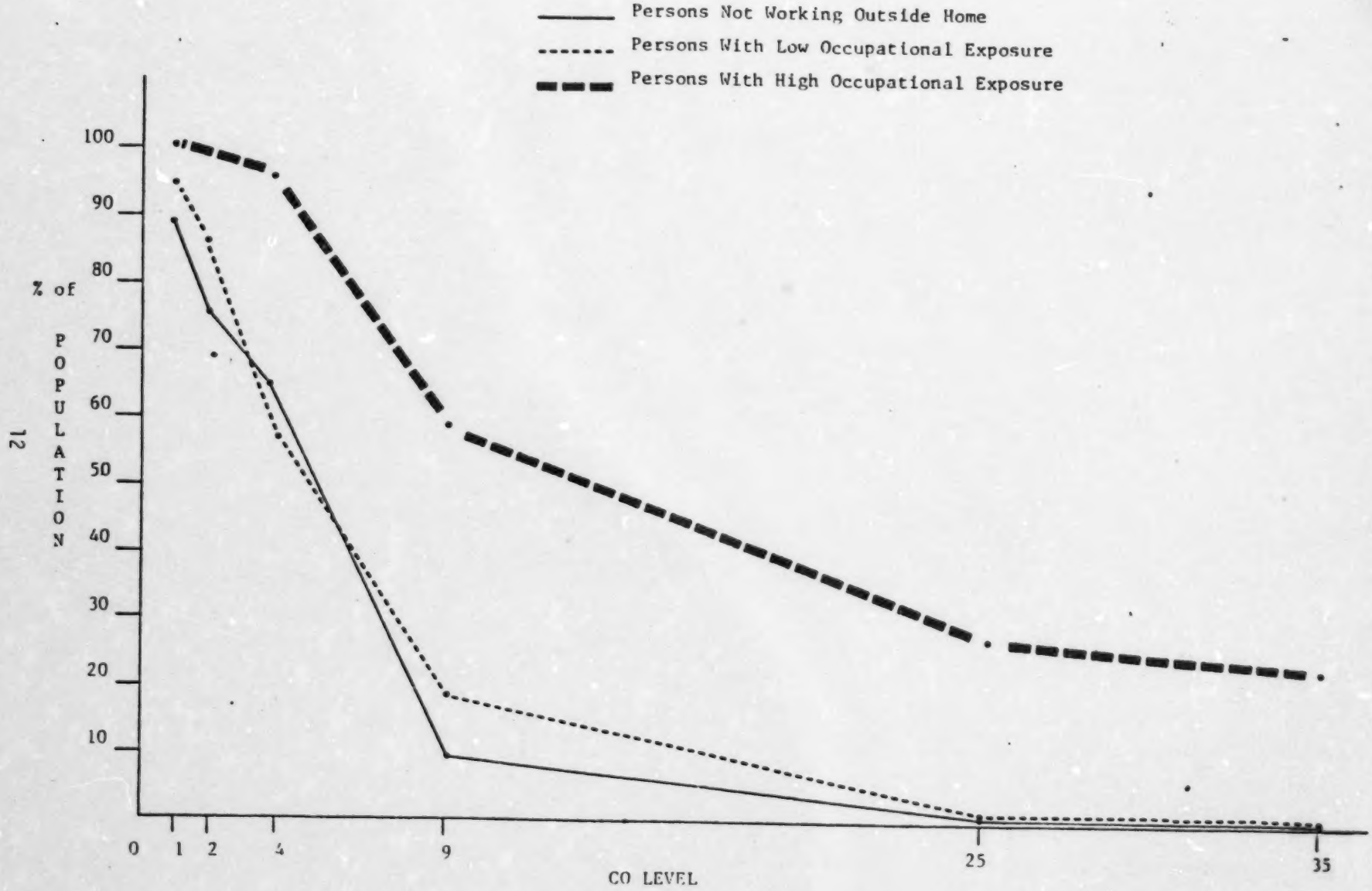

Figure 4. Maximum hourly CO concentrations for selected commuting statuses, Washington, D.C.

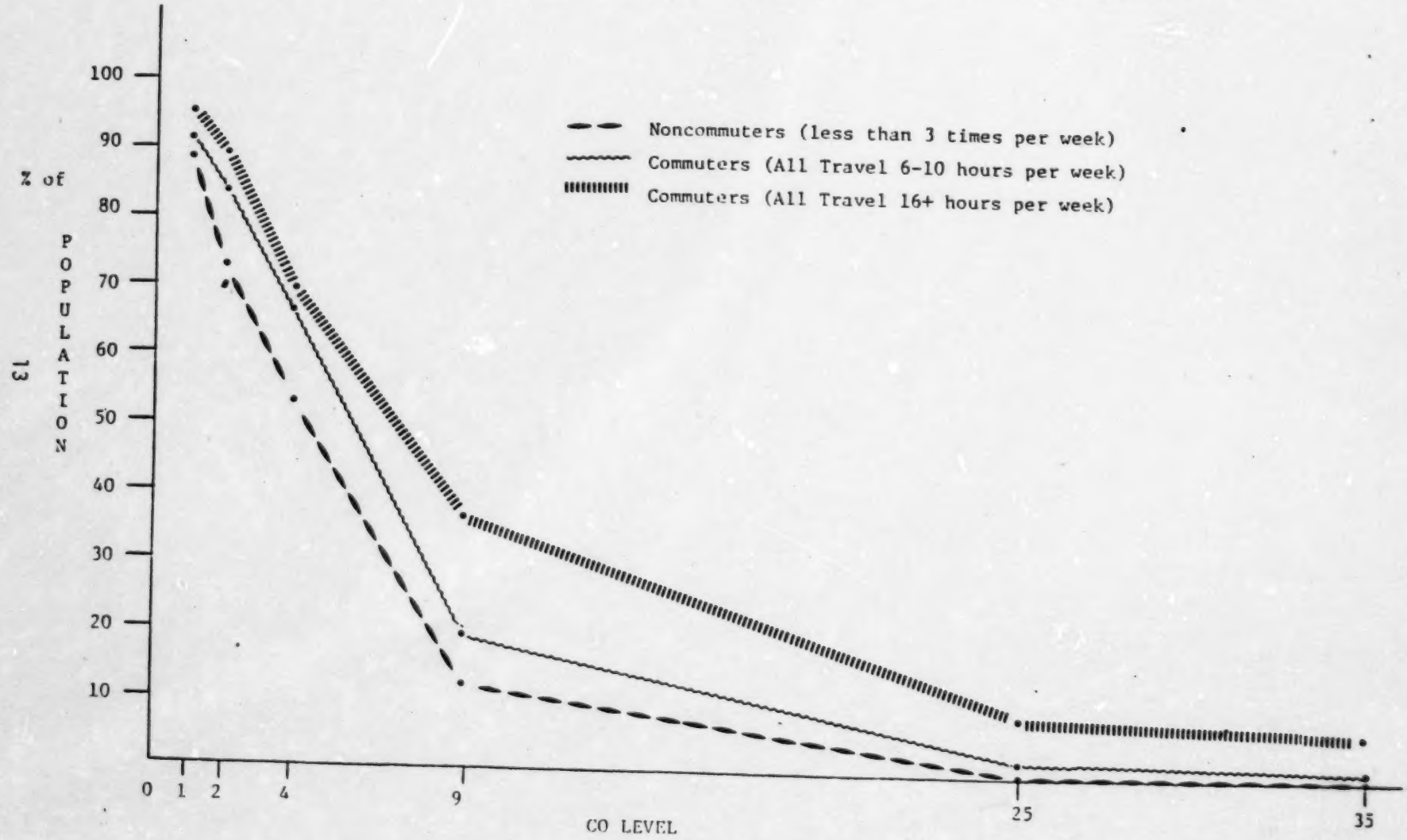

Table I. Summary of maximum hourly CO concentration data.

Population Subgroup	# in Samp.	Est. # in Exposed Popu.	Est. % of Total Popu.	Est. Avg. CO Conc. (ppm)	Approx. SE of Av. CO Conc. (ppm)	Estimated Percent of Exposed Population With CO Concentration > X PPM					
						X=1	X=2	X=4	X=9	X=25	X=35
All Persons All Days	712	1215539	100.00	6.74	0.46	92.97	87.93	61.76	18.23	1.88	1.28
All Persons Low CO Days [a] [c]	491	1215539	100.00	6.71	0.60	92.47	81.33	58.66	17.42	2.13	1.46
All Persons High CO Days	221	1215539	100.00	6.82	0.25	94.66	88.31	72.23	20.97	1.03	0.65
Persons Not Working Outside Home	181	362366	29.81	5.22	0.36	89.24	76.48	64.06	8.65	0.35	0.35
Persons W/Low Occupational Exposure	503	796704	65.54	6.34	0.31	94.17	84.69	58.30	19.86	0.72	0.10
Persons W/High Occupational Exposure [b]	27	56244	4.63	22.11	5.64	100.00	99.47	95.86	57.03	28.11	23.95
All Persons Weekdays [a]	551	1215539	100.00	7.35	0.71	93.72	84.88	62.31	21.97	2.37	1.82
All Persons Weekend Days	161	1215539	100.00	5.30	0.37	91.23	78.35	60.49	9.49	0.71	0.00
Non-Commuters (<3 Times Per Week)	105	167155	13.75	4.94	0.33	88.90	73.58	53.17	12.12	0.00	0.00
Commuters (All Travel 0-5 hrs/wk)	180	299240	24.62	5.04	0.27	95.20	80.80	54.69	7.63	0.39	0.00
Commuters (All Travel 6-10 hrs/wk)	233	415748	34.20	6.70	0.27	91.26	84.06	66.58	19.25	1.91	1.31
Commuters (All Travel 11-15 hrs/wk)	104	156340	12.86	7.08	1.51	94.27	86.57	65.17	24.84	0.68	0.00
Commuters (All Travel 16+ hrs/wk)	73	151821	12.49	12.01	3.47	95.25	89.11	69.44	36.72	8.33	6.64
Unknown Commuting Status	17	25236	2.08	5.56	0.98	100.00	91.65	55.80	15.73	0.00	0.00
Gas Stove at Residence -- Vented	187	370703	30.50	6.40	0.85	94.52	91.41	64.73	13.61	0.75	0.50
Gas Stove at Residence -- Not Vented	176	300726	24.74	7.05	0.73	98.23	90.26	66.33	21.58	2.06	0.25
No Gas Stove at Residence	325	504262	41.48	6.82	0.76	88.55	71.81	56.00	20.27	2.49	2.31
Presence of Gas Stove Unknown	24	39847	3.28	6.47	1.19	94.86	89.34	77.63	10.27	3.18	3.18

a Population counts have been adjusted to conform to those for the overall population.
b See reference 1 for definitions of high occupational exposure.
c High CO days were arbitrarily defined for this report as days when any of the fixed site monitors in the Washington, D.C. area had at least one hour greater than 10 ppm.

Table II. Summary of maximum 8-hour CO concentration data.

Population Subgroup	# in Samp.	Est. # in Exposed Popu.	Est. % of Total Popu.	Est. Avg. CO Conc. (ppm)	Approx. SE of Av. CO Conc. (ppm)	Estimated Percent of Exposed Population With CO Concentration > X PPM					
						X=1	X=2	X=4	X=9	X=15	X=25
All Persons All Days	712	1215539	100.00	2.79	0.08	78.62	56.46	15.82	3.90	0.44	0.20
All Persons Low CO Days [a]	491	1215539	100.00	2.72	0.11	76.34	53.40	13.91	4.10	0.45	0.15
All Persons High CO Days	221	1215539	100.00	3.03	0.15	86.32	66.80	22.28	3.23	0.38	0.38
Persons Not Working Outside Home	181	362366	29.81	2.35	0.18	74.55	56.19	8.55	1.01	0.00	0.00
Persons W/Low Occupational Exposure	503	796704	65.54	2.66	0.15	78.99	53.72	15.74	3.51	0.34	0.18
Persons W/High Occupational Exposure [b]	27	56244	4.63	7.51	0.68	99.47	97.33	64.01	28.11	4.70	1.88
All Persons Weekdays [a]	551	1215539	100.00	2.94	0.14	81.30	56.95	18.61	4.46	0.62	0.29
All Persons Weekend Days	161	1215539	100.00	2.43	0.44	72.36	55.33	9.32	2.59	0.00	0.00
Non-Commuters (<3 Times Per Week)	105	167155	13.75	2.30	0.17	70.59	51.38	12.50	0.66	0.00	0.00
Commuters (All Travel 0-5 hrs/wk)	180	299240	24.62	2.35	0.18	75.89	52.52	7.52	1.29	0.00	0.00
Commuters (All Travel 6-10 hrs/wk)	233	415748	34.20	2.79	0.17	76.23	57.76	17.30	4.64	1.11	0.60
Commuters (All Travel 11-15 hrs/wk)	104	156340	12.86	3.22	0.82	82.38	53.86	23.52	6.76	0.45	0.00
Commuters (All Travel 16+ hrs/wk)	73	151821	12.49	3.80	0.85	93.35	65.41	24.75	8.33	0.00	0.00
Unknown Commuting Status	17	25236	2.08	2.55	0.25	91.65	77.78	10.61	0.00	0.00	0.00
Gas Stove at Residence -- Vented	187	370703	30.50	2.99	0.20	88.10	67.79	15.60	1.95	0.50	0.50
Gas Stove at Residence -- Not Vented	176	300726	24.74	3.03	0.27	90.78	65.48	19.52	3.59	0.39	0.21
No Gas Stove at Pesidence	325	504262	41.48	2.55	0.12	64.23	43.93	14.48	5.58	0.45	0.00
Presence of Gas Stove Unknown	24	39847	3.28	2.11	0.53	80.78	41.66	7.03	3.18	0.00	0.00

a Population counts have been adjusted to conform to those for the overall population.
b See reference 1 for definitions of high occupational exposure.

Table III. Summary of CO exposure levels, by type of activity -- ranked according to mean CO level.

Type of Activity	Estimated Size of of Exposed Population, as Percent of Total Population	Average Time Duration (hours)	Est. Average CO Conc. (ppm)	Estimated % of Exposed Popu. With CO Level > 4 ppm	Percentile Estimates of Exposed Population CO Levels (ppm), Selected Percentile Points				
					10	25	50	75	90
In parking garage or lot	10.61	0.30	6.93	41	0.26	1.41	3.33	11.03	21.35
Transit, travel	93.93	2.07	4.51	44	1.03	2.16	3.49	6.20	8.42
Errands, shopping	35.77	0.75	2.50	18	0.10	0.84	1.84	3.14	4.83
Cooking	49.98	2.14	2.10	14	0.05	0.44	1.54	3.17	4.39
Doctor or dentist office	3.60	0.85	2.07	6	0.05	0.50	1.29	2.03	2.64
Eating, drinking	65.48	1.78	1.99	11	0.05	0.41	1.40	3.07	4.04
Work, business meeting	50.48	6.63	1.97	10	0.05	0.40	1.05	1.93	4.10
Unknown activity	73.26	1.30	1.86	10	0.05	0.14	1.02	2.21	3.88
School or study	8.33	2.97	1.79	12	0.05	0.07	0.74	1.63	4.49
Outside-activity unspecified	13.09	0.48	1.74	13	0.05	0.09	1.05	1.79	4.42
Inside house - chores	39.62	2.18	1.70	5	0.05	0.31	1.14	2.99	3.36
Laundry	14.65	0.85	1.57	4	0.05	0.12	0.97	3.14	3.42
Leisure activities	72.96	3.68	1.49	7	0.05	0.29	0.91	2.10	3.10
Personal activities	79.24	1.10	1.35	6	0.05	0.05	0.69	2.05	3.74
Inside house-misc. activities	46.71	2.21	1.28	5	0.05	0.15	0.79	1.67	2.77
Sports, exercise	10.52	1.16	1.21	4	0.05	0.18	0.33	1.74	2.27
Miscellaneous plus suspected sleep	15.07	10.64	1.10	4	0.05	0.06	0.81	1.38	2.10
Church, political mtg., etc.	4.94	1.85	0.91	5	0.05	0.17	0.48	0.96	2.50
Outside house - chores	11.41	1.00	0.89	1	0.05	0.05	0.30	1.12	1.21
Sleeping	85.97	8.62	0.85	2	0.05	0.05	0.33	1.26	1.96

Table IV. Summary of CO exposure levels, by type of environment.

Activity	# in Samp.	Est. # in Exposed Popu.	Est. % of Total Popu.	Est. Avg. CO Conc. (ppm)	Approx. SE of Av. CO Conc. (ppm)	Avg. Time Duration (Hrs)	Estimated Percent of Exposed Population With CO Concentration > X PPM					
							X=1	X=2	X=4	X=9	X=25	X=35
In Transit	662	1141746	93.93	4.51	0.17	2.07	91.09	76.44	43.79	8.76	0.31	0.23
Walk, Jog, Bicycle	226	355550	29.25	2.42	0.29	0.82	71.93	46.44	19.89	1.42	0.00	0.00
Car	592	1029688	84.71	5.05	0.14	1.76	92.35	80.08	47.37	10.65	0.93	0.36
Other	130	214632	17.66	3.59	0.30	1.25	73.09	61.19	31.92	9.96	0.00	0.00
Indoors - At Residence	705	1215539	100.00	1.19	0.10	17.63	44.18	18.90	3.15	0.30	0.00	0.00
Sleep [a]	705	1215539	100.00	0.88	0.09	9.01	31.99	9.13	2.25	0.39	0.00	0.00
Cook - Gas Stove	186	405334	33.35	2.78	0.20	1.96	78.73	61.56	21.93	3.67	0.00	0.00
Cook - Other or Unknown	192	279487	22.99	1.40	0.19	1.79	41.57	22.24	11.64	0.70	0.00	0.00
Other	701	1203513	99.01	1.51	0.12	7.63	50.75	26.60	6.56	0.38	0.00	0.00
Indoors - Not at Residence	583	924540	76.06	2.04	0.15	5.44	53.58	29.93	10.26	4.72	0.11	0.00
Office	349	534110	43.94	1.86	0.27	5.80	55.10	28.42	8.74	4.01	0.12	0.00
Store	225	372479	30.64	2.49	0.49	1.42	66.01	47.55	16.78	3.76	0.00	0.00
Restaurant	170	313488	25.79	2.09	0.32	1.19	60.10	37.98	11.46	0.84	0.47	0.00
Parking Garage	59	87187	7.17	10.36	4.43	0.81	81.48	74.94	53.60	34.13	8.99	8.99
Other	257	383216	31.53	1.85	0.14	2.49	41.15	21.89	11.13	5.85	0.28	0.00
Outdoors	243	407695	33.54	2.62	0.28	0.96	51.46	30.27	22.05	6.79	0.60	0.25
Near Road, Gas Sta., Construction Site	164	291354	23.97	2.65	0.20	0.84	55.46	35.51	23.45	7.57	0.49	0.00
Parking Area	54	80893	6.65	4.67	0.95	0.32	65.89	38.42	24.20	11.91	1.27	1.27
Other	79	189022	8.97	0.91	0.21	1.11	23.39	14.85	4.05	1.90	0.00	0.00
Unknown	4	11032	0.91	2.82	0.34	0.28	89.69	89.69	0.00	0.00	0.00	0.00

a Estimates may be biased due to inclusion of other activities for some sample members.